POPULATION DYNAMICS AND MANAGEMENT OF FISHERIES RESOURCES

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Abstract We investigate importance to monitor the relative population size for population management. If we assume the stationary population, the degree of overexploitation is usually underestimated. Cuban Hawksbill turtles was this case. However, if we know the trends in relative population dynamics, we can improve estimate of fishing mortality and absolute population size.

***Keywords*:** adaptive management, Hawksbill turtle, life table, monitoring, overexploitation

Introduction

In fisheries resources including marine turtles, there is large uncertainty in life history, population sex ratio, survivorship curve, growth curve, population size, and age structure. In addition, these parameters will be variable in time and space, and among individuals. The magnitude of variation is often entirely uncertain.

Recently, adaptive management has been recognized as a useful and practical method to manage population or ecosystem with uncertainties. Adaptive management consists of accountability for uncertainties, adaptability for dynamical change of stock status, and continuous monitoring (Christensen et al. 1996). Data obtained from commercial fishery are indispensable in adaptive management. Successive monitoring is also important. We first introduce theoretical concerns with a fisheries model for harvest of Hawksbill turtles in the Cuban Archipelago (Doi et al. 1992, Heppel and Crowder 1996). We discuss a harvest-based estimator for absolute population size in fisheries and wildlife management.

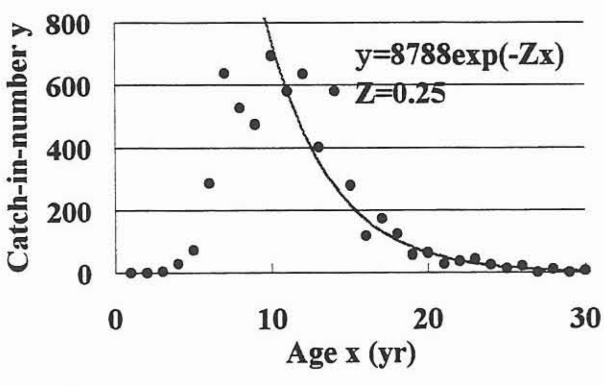

Fig. 1. Catch-n-number and estimation of total mortality coefficient Z from DOIRAP method (Doi et al. 1992, see also Tokunaga 2000).

DOIRAP Method

If we obtain catch-at-age (the number of harvested turtles at each age) data of sea turtles for a single year, how to make diagnosis of this stock? Doi et al. (1992) developed "DOIRAP" method under assumptions that (1) age identification is correct; (2) age-structure is stable; (3) fishing mortality on adult is identical irrespective of ages; and (4) population size is kept to be constant (see also Heppel and Crowder 1996, Tokunaga 2000). We obtain the regression line of log-linear relationship between age x year and catch-in-number ($y(x)$) as $\hat{y}(x)=8788e^{-Zx}$, for $x \geq 10$, where Z is 0.25/yr and is the total mortality coefficient (Fig. 1). The relative fishing mortality under age 10 years is assumed to be given as $y(x)/\hat{y}(x)$. From the age of maturity (x_m), rate of maturity ($E(x)$) and body weight ($W(x)$) at age x, Doi et al. (1992) estimated the natural mortality coefficient M after recruitment where population biomass is maximized at age of maturity $W(x_m)\exp(-Mx_m)$. They expected a life history parameter x_m is evolutionarily determined to maximize the expected number of offspring per mother. However, many species of fisheries resources including turtles, bivalves and iteroparous fishes grow after the age of maturity, which is called indeterminate growth. For organisms with indeterminate growth, the mortality that maximizes population biomass at the age of maturity is not optimal. Anyway, the fishing mortality coefficient $F(x)$ is obtained as $F(x)=Z-M$ for $x \geq x_m$ and $F(x)=(Z-M)y(x)/\hat{y}(x)$ for $x<x_m$. The survival rate from recruitment to age x ($S(x)$) is $S(x)=\exp[-\square_t(M+F(t))]$

Under these assumptions, Doi et al. (1992) investigated effects of fisheries on the turtles stock. We can also estimate spawning stock biomass per recruit (SPR) from parameters x_m, $W(x)$, $E(x)$, $F(x)$ and M as SPR = $\square_x W(x)E(x)S(x)$ if the fecundity is proportional to body weight of an individual. For the Cuban Hawksbill turtles in 1992, the ratio of SPR under fished to SPR under unfished (F=0 for any age), usually denoted by %SPR (Mace 1994), is less than 25%, which implies strong overfishing (Tokunaga 2000)

The real %SPR is probably smaller than 25%, because DOIRAP method assumed the stationary population. If the population is declining, the total mortality coefficient is underestimated. Table 1 illustrates a hypothetical example. If the annual survival rate s=70%/yr and the population decline rate d=10%/yr, the ratio of $N(a+1,y)$ to $N(a,y)$ is $s/(1-d)$=77.8%. Underestimation of Z results in underestimation of the degree of overfishing and %SPR (Tokunaga 2000).

Harvest-based estimator of population size

Table 1. The stock-in-number at age a in year y of a hypothetical population.

$N(a,y)$	2000	2001	2002	2003	2004
1	1,000	900	810	729	656
2	778	700	630	567	510
3	605	544	490	441	397
4	471	423	381	343	309
5	366	329	296	267	240

Cuban Hawsbill turtles have been conserved since 1995. The average number of harvested turtles was 4700 during 1968-1990, while that was 399 during 1995-1999. The total population size is still uncertain.

If we estimate the population declining rate, the above method could be improved and avoid farther overexploitation by setting a threshold of relative population size (management plan in Hokkaido Island, see http://www2.ori.u-tokyo.ac.jp/~matsuda/deer-e.html). Trend in relative population size is important for decision-making.

In addition, if we use trends in relative population size (denoted by P_t), the number of catch (C_t), and the rate of natural population increase (r), then we can roughly estimate the absolute population size (N_t). The number of individuals in year t is given as $N_t = rN_{t-1}-C_t$. Since $(P_t/P_{t-1}) = (N_t/N_{t-1})$, $N_t = C_{t-1}P_t/(rP_{t-1}-P_t)$. Despite of a large uncertainty in the estimate of P_t, trends in relative population size and catch data will give lower and upper limit of absolute population size.

If we know the sex ratio and/or age composition in catch data, these are also useful in a better population estimator. Catch per unit effort (CPUE) and the number of egg-laying sites are good indicators of relative population size. Catch data and CPUE in the age of overexploitation are also useful, because the larger change of exploitation rate gives the better information in the absolute population size. We regard change in management action as an experiment. The overexploitation era will be an object lesson to adaptive management, if we collect and publish the data at the age of overexploitation.

If we execute an effective management for a long-lived animal, we should note that the population decline continue after the beginning of the management action. This is because the number of recruits that are born before the management action may continue to decline after the management action is introduced. This is called the momentum in demography. We introduce a new method of population estimation, and the momentum in demography for fisheries management.

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